Anti-degradation Protection of Water Quality for the Delaware River Basin: Expansion of the Control Point Approach to Monitoring and Assessment

National Water Quality Monitoring Conference

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Delaware River Basin Commission

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NATIONAL PARK SERVICE

National Wild and Scenic Reaches in the Delaware Basin

Special Protection Waters (SPW) Policy: "No measurable change to Existing Water Quality (EWQ) unless due to natural conditions"

SPW rules cover ≈6,780 of the 13,800 sq. mi. Delaware River Basin watershed area

Monitored by the DRBC/NPS Scenic Rivers Monitoring Program (SRMP)

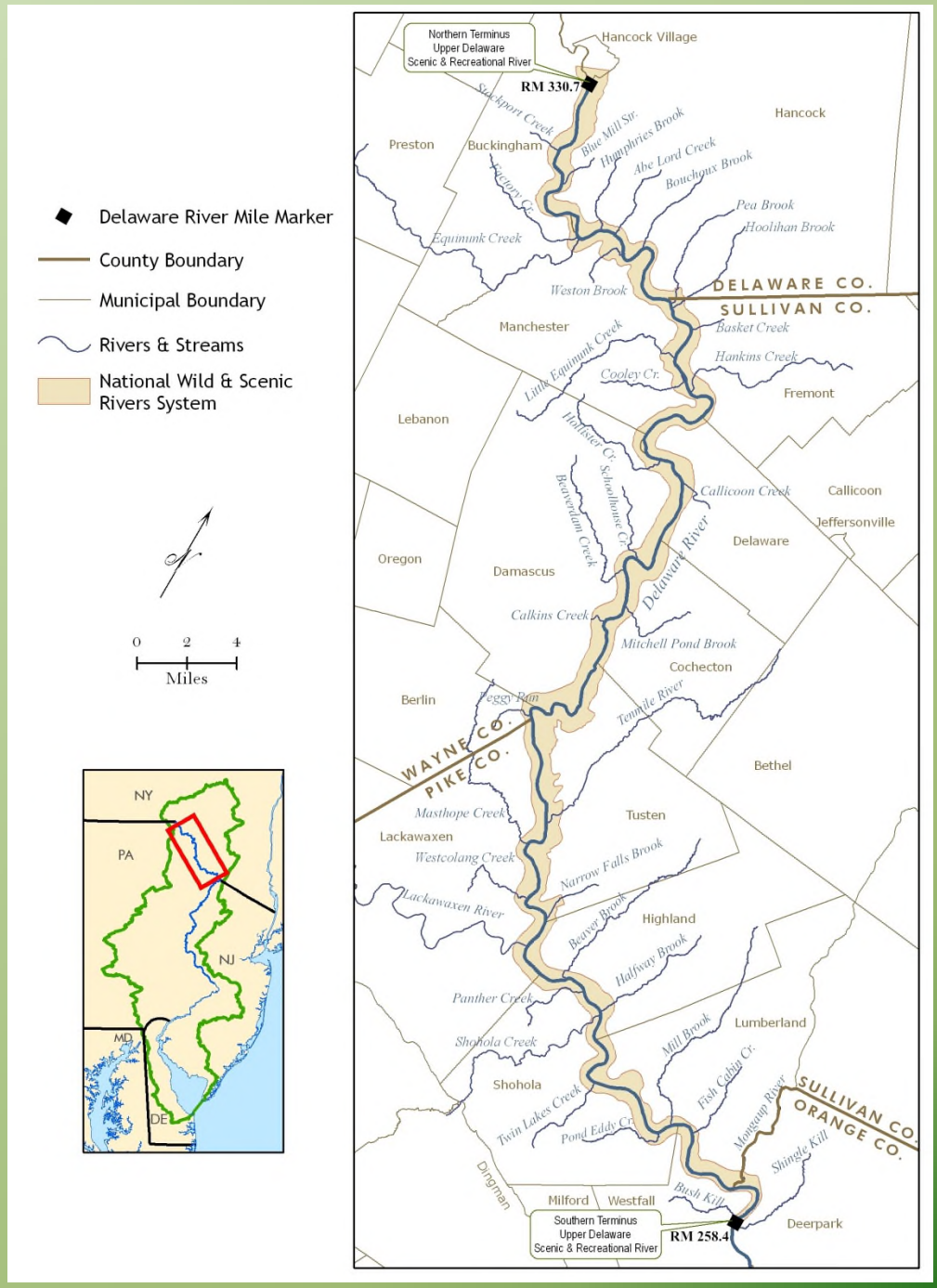
Stream Segments Designated by DRBC as SPW in 1992

Upper Delaware

The Upper Delaware Scenic and Recreational River (UPDE) as *Outstanding Basin Waters*

(Comparable to CWA Tier 3 Anti-Degradation)

OBW



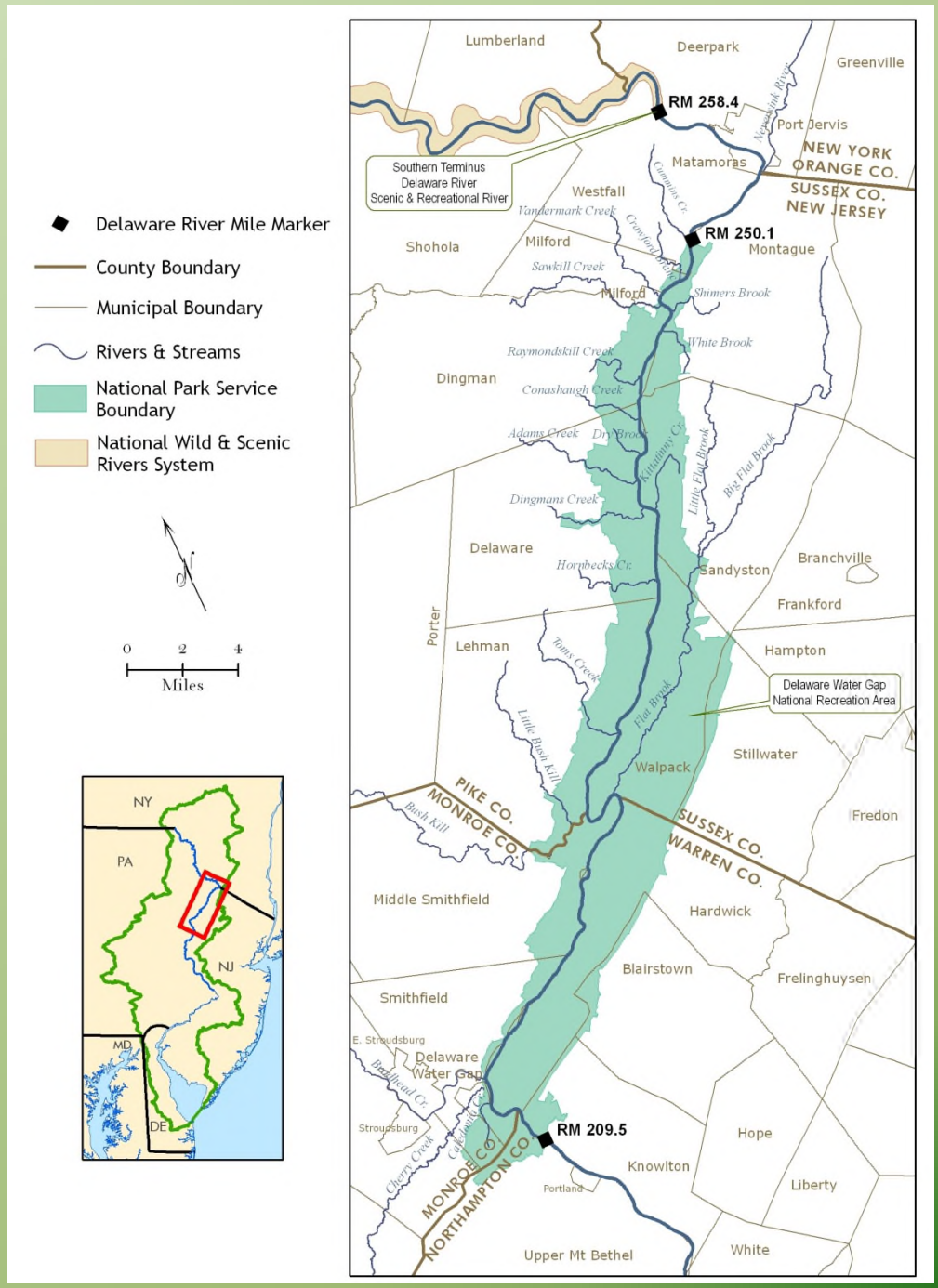
Stream Segments Designated by DRBC as SPW in 1992

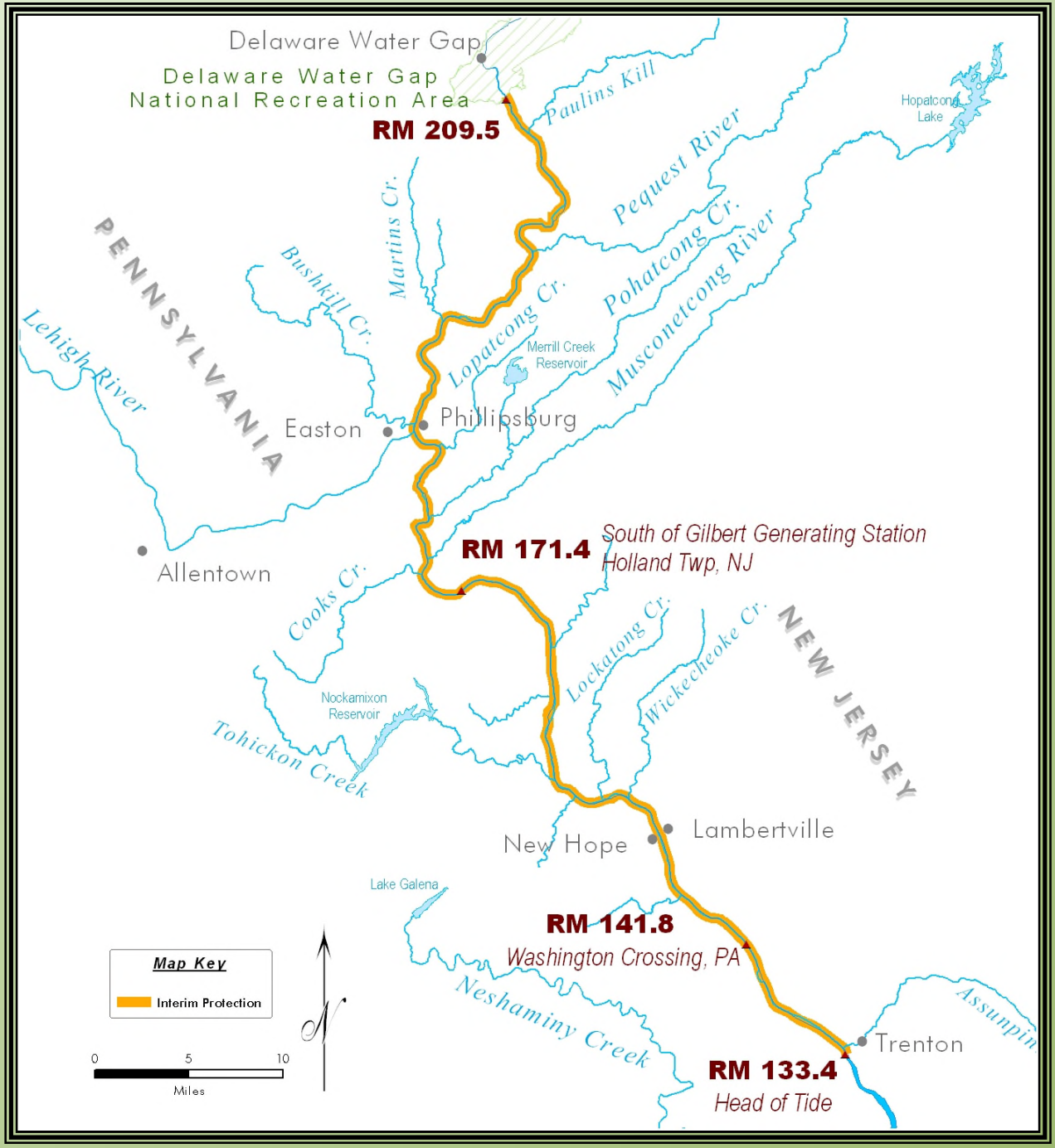
Middle Delaware

- The 8.5-mile stretch of river (Tri-State) between the Upper Delaware Scenic and Recreational River and the Delaware Water Gap National Recreation Area classified as *Significant Resource Waters (similar to CWA Tier 2)*

- Delaware Water Gap National Recreation Area (DEWA) classified as *Outstanding Basin Waters*

OBW **SRW**





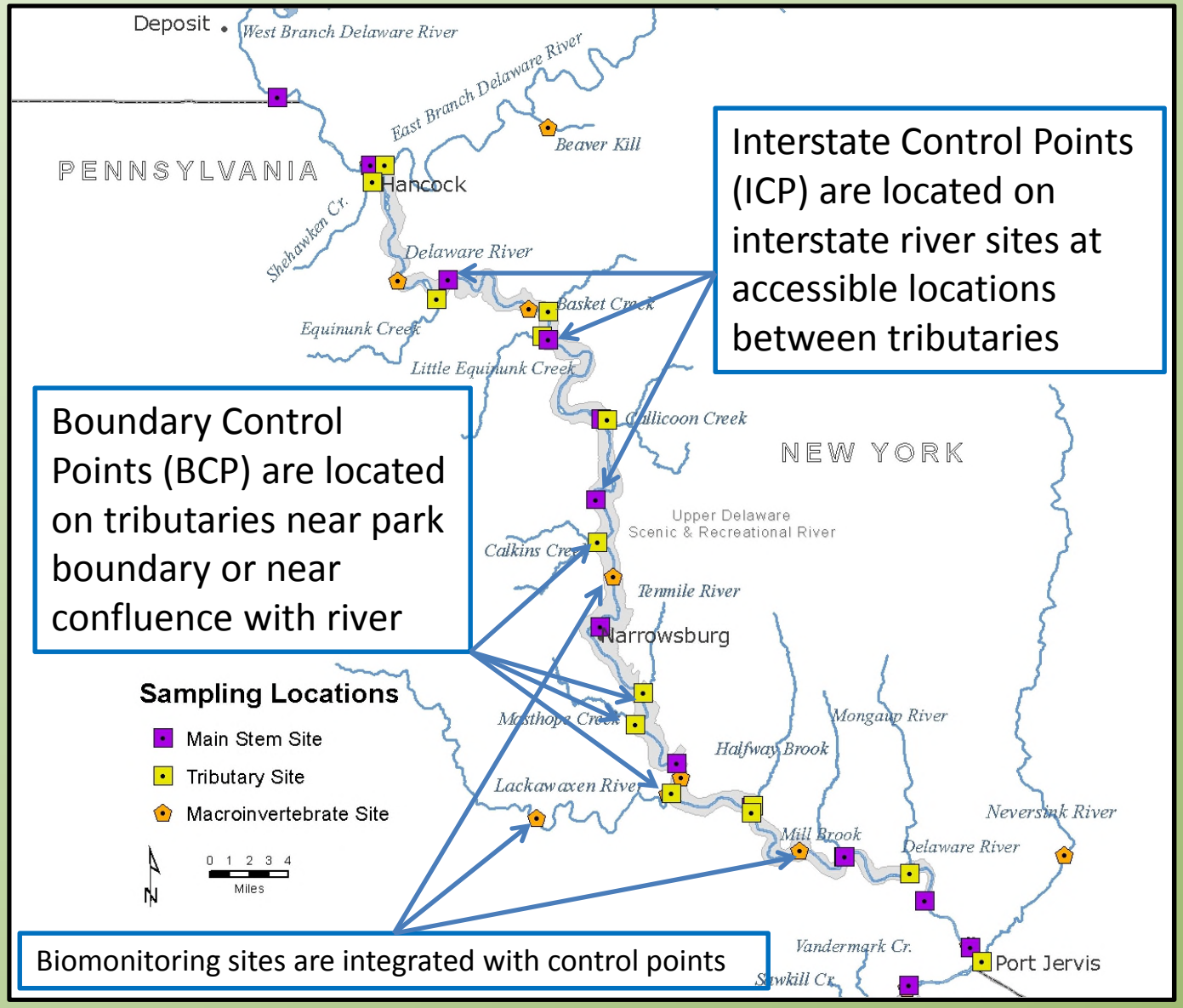
Stream Segments Designated by DRBC as SPW in 2007

Lower Delaware

The Lower Delaware Scenic and Recreational River (LDEL) as *Significant Resource Waters*

SRW

SRMP Upper Delaware (UPDE) Sites



Control Point approach to monitoring arose from:

Narrow shape of park boundaries;

DRBC river-centric jurisdictional responsibilities;

Applicability to QUAL2K modeling for permits;

Tracking water quality down a 200+ mile longitudinal corridor

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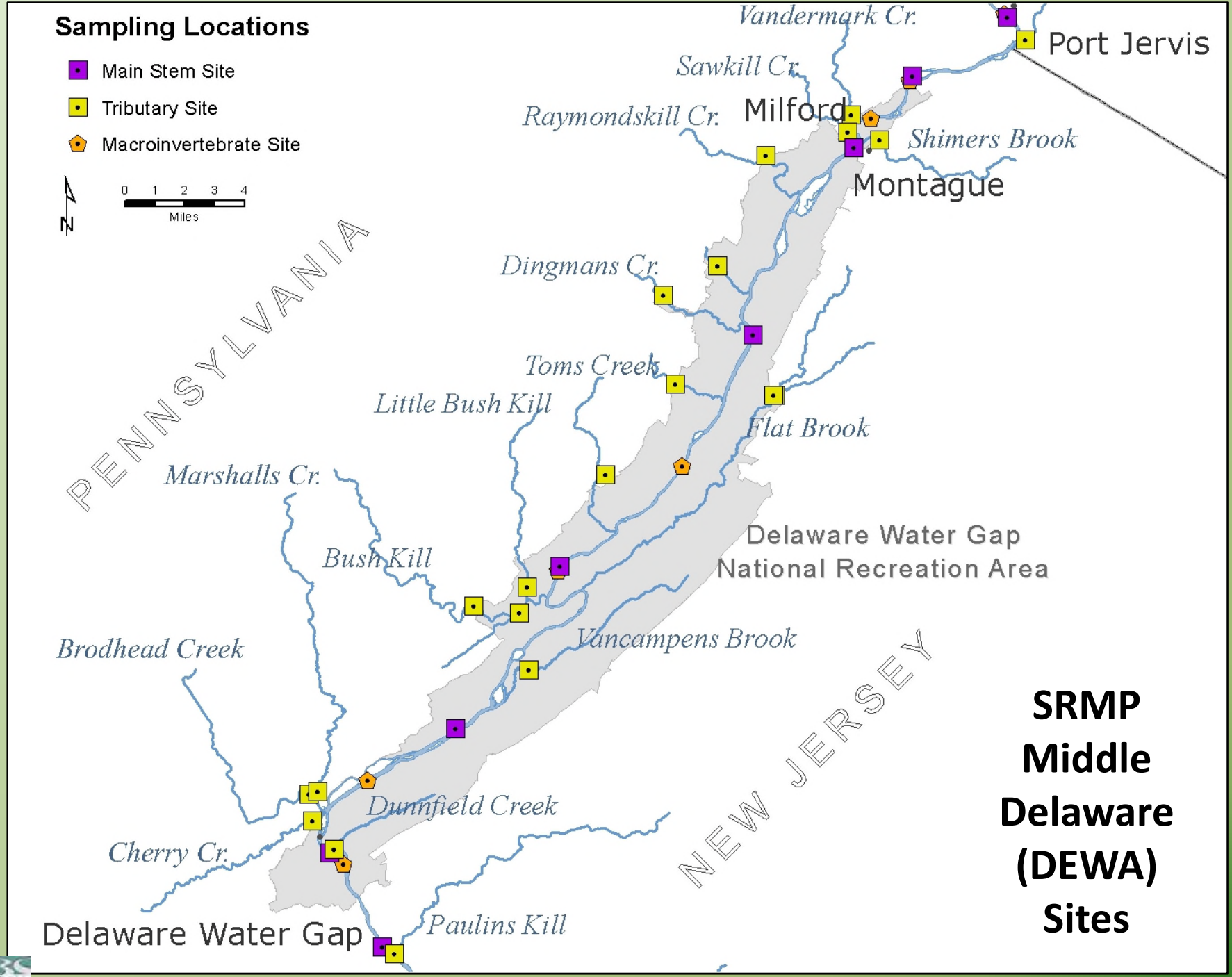


SRMP Middle Delaware (DEWA) Sites

SRMP Lower Delaware (LDEL) Sites

Why Conversion of UPDE and DEWA Existing Water Quality from Reach-Wide (1992) to Site-Specific (2011)?

- **Breidt et. al. (1989)***
  - Statistically analyzed EWQ for NPS and DRBC
  - Saw differences between sites within regulatory reaches
  - Did not advocate reach-wide targets (ignored by managers)
  - Recommended non-parametric approach (ignored…)
  - Reach-wide targets were kept in rules to avoid delays
- **Lower Delaware 2000-2004 target development followed Breidt et. al. approach; are non-parametric and site-specific; and have worked well for project review and assessment tasks.**
- **Assessment task was not possible 1992-2013 in Upper and Middle Delaware using reach-wide targets; parent data were unrecoverable, unevenly sampled within reaches, and applied replacement values to non-detect measurements.**

* Breidt, F.J., D.C. Boes, J.I Wagner, and M.D. Flora. 1991. Antidegradation water quality criteria for the Delaware River: a distribution-free statistical approach. Water Resources Bulletin 27(5): 849-858.

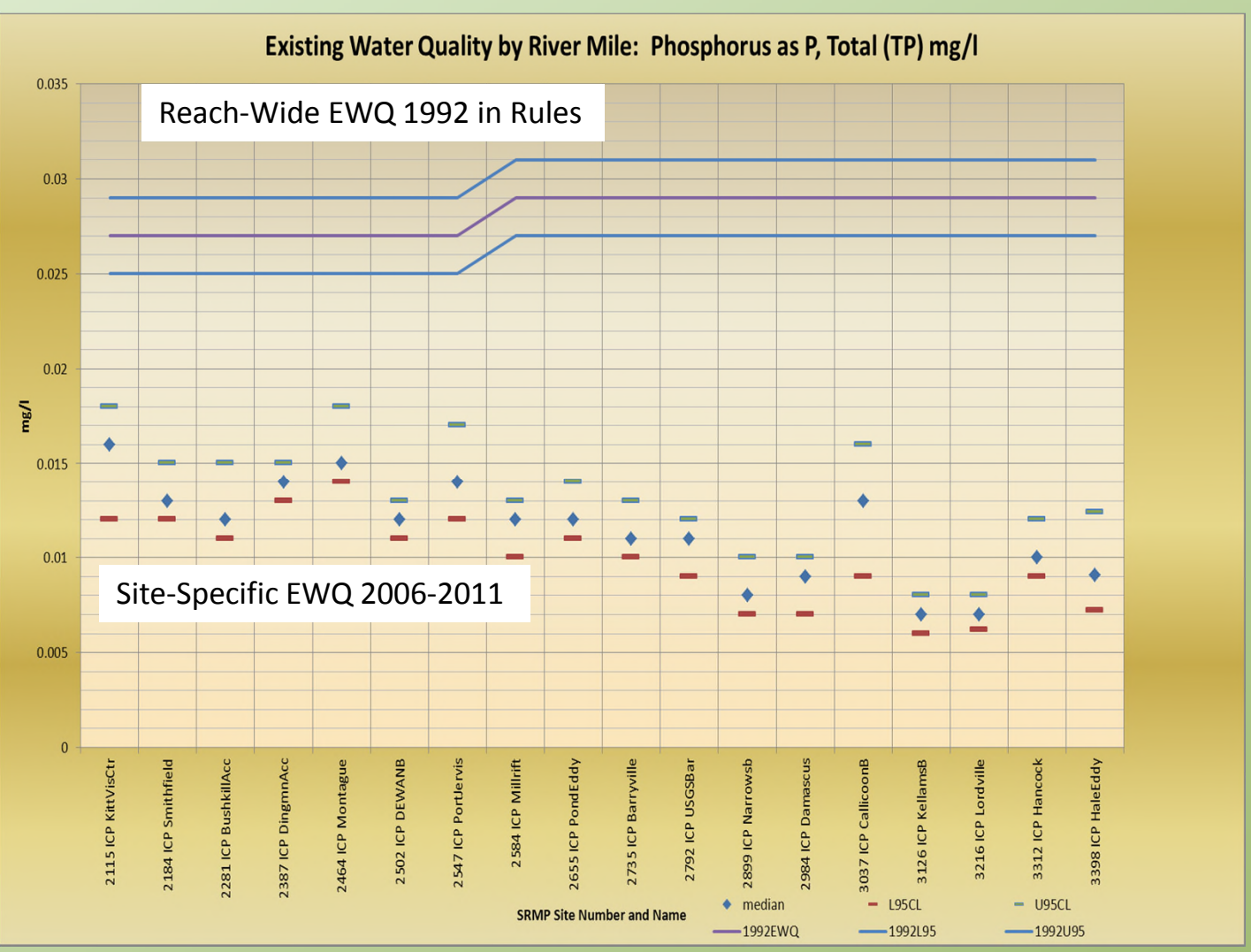
Purposes for EWQ Targets

- Project Review and Permitting Waste-Water Treatment Facilities
  - use upper 95% confidence limits of median concentrations of Ammonia, DO, Fecal Coliform, Nitrate + Nitrite, Total Phosphorus, TKN, TSS for design of treatment facilities to prevent water quality degradation.
- Monitoring and Assessment of Measurable Change to EWQ:
  - Create site-specific baseline (4-5 years, n approx. 50)
  - Statistically compare subsequent Assessment Rounds (3-5 years, n = 30 to 50) to baseline set.
- Review measurable changes and feed back to permitters and planners, work with states, municipalities and NGO's to solve potential problems before water quality degrades (cheap), instead of TMDL's after criteria are violated ($$$$$.....).
- Demonstrated success in Neversink Watershed, NY (rept. in progr.)

Scenic Rivers Monitoring Program Methods

- 2006-2011 Upper and Middle Delaware Study for conversion of reach-wide EWQ to site-specific EWQ
  - May to September bi-weekly samples. River sites are composite samples (if at bridges) and tributary samples are center-channel grabs. 47 sites (20 UPDE, 25 DEWA, 2 new LDEL)
- Some USGS and State data were included, as long as various conditions were met
  - generally 1999-2009 from NWIS and STORET (many duplicate records!)
  - Sampling must represent range of hydrologic conditions; spread across multiple months and years; same lab methods; demonstrated good QAQC at very low concentrations; etc.
- Parameters (SRMP Lab was Academy of Natural Sciences of Drexel Univ.):
  - Field measurements (DO, SpC, pH, WT, AT) – YSI meters
  - Conventionals (Alk, Hd, TSS, TDS, Cl, Turb)
  - Nutrients (Ammonia, Nitrate + Nitrite, TKN, TN, Orthophosphate, TP)
  - Bacteria (Fecal Coliform, E. coli, Enterococcus) – QC Labs, Inc.
  - Some Metals & other ions if data available (Ca, Mn, Mg, Fe, SO4)
  - 2009-2010 Marcellus (archived) (Al, Ba, Ca, Fe, Mg, Mn, K, Na, Sr, SO4)
- Almost NO non-detects in newer data – low level MDL's are a must for antidegradation monitoring.

UPDE and DEWA EWQ: Reach-Wide 1992 vs. Site Specific 2011

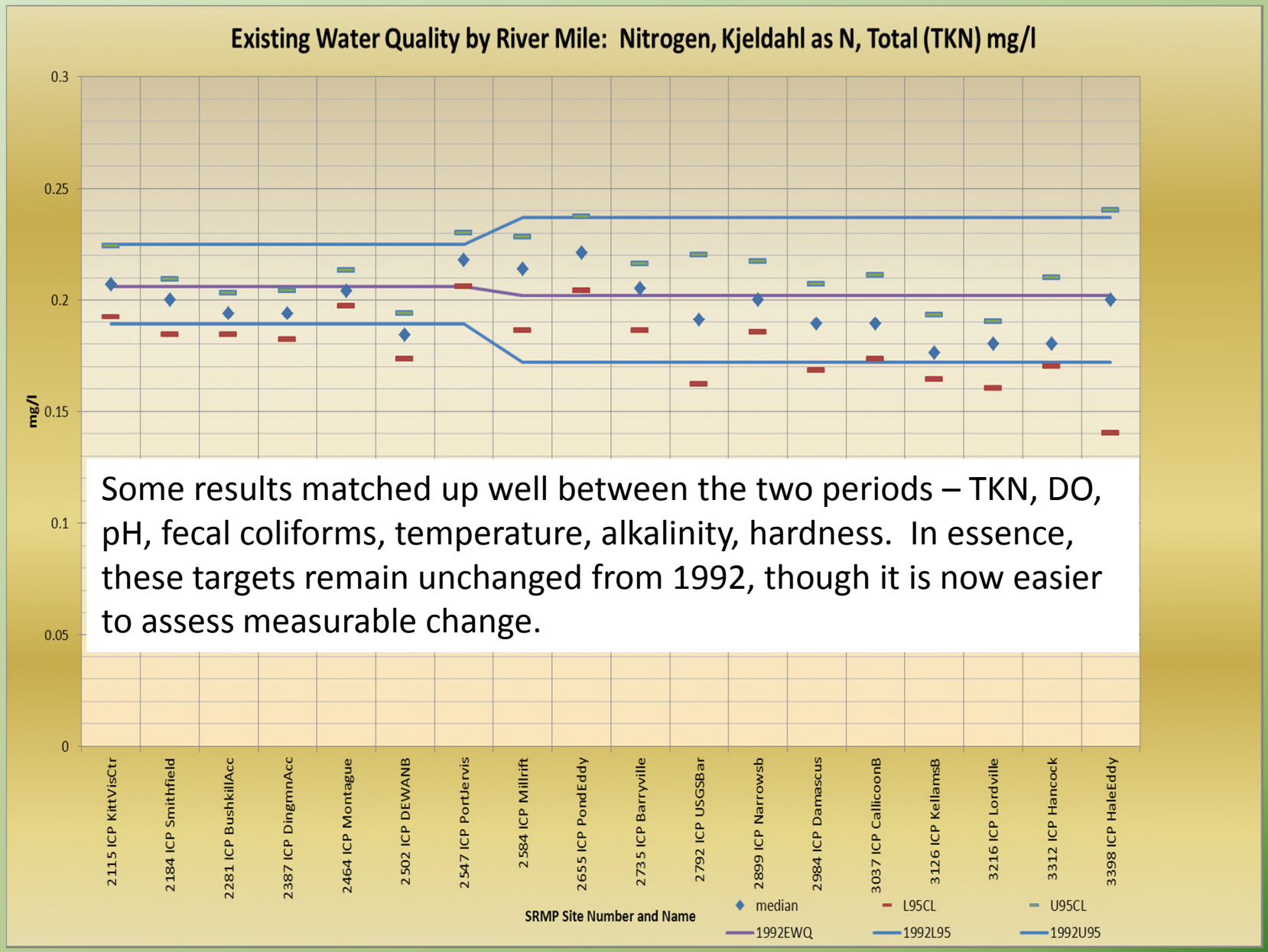


Less Confidence, hard to assess changes, uneven geographic distribution of data

Improved Confidence, easy to assess changes within and between sites, all data adhere to program objectives

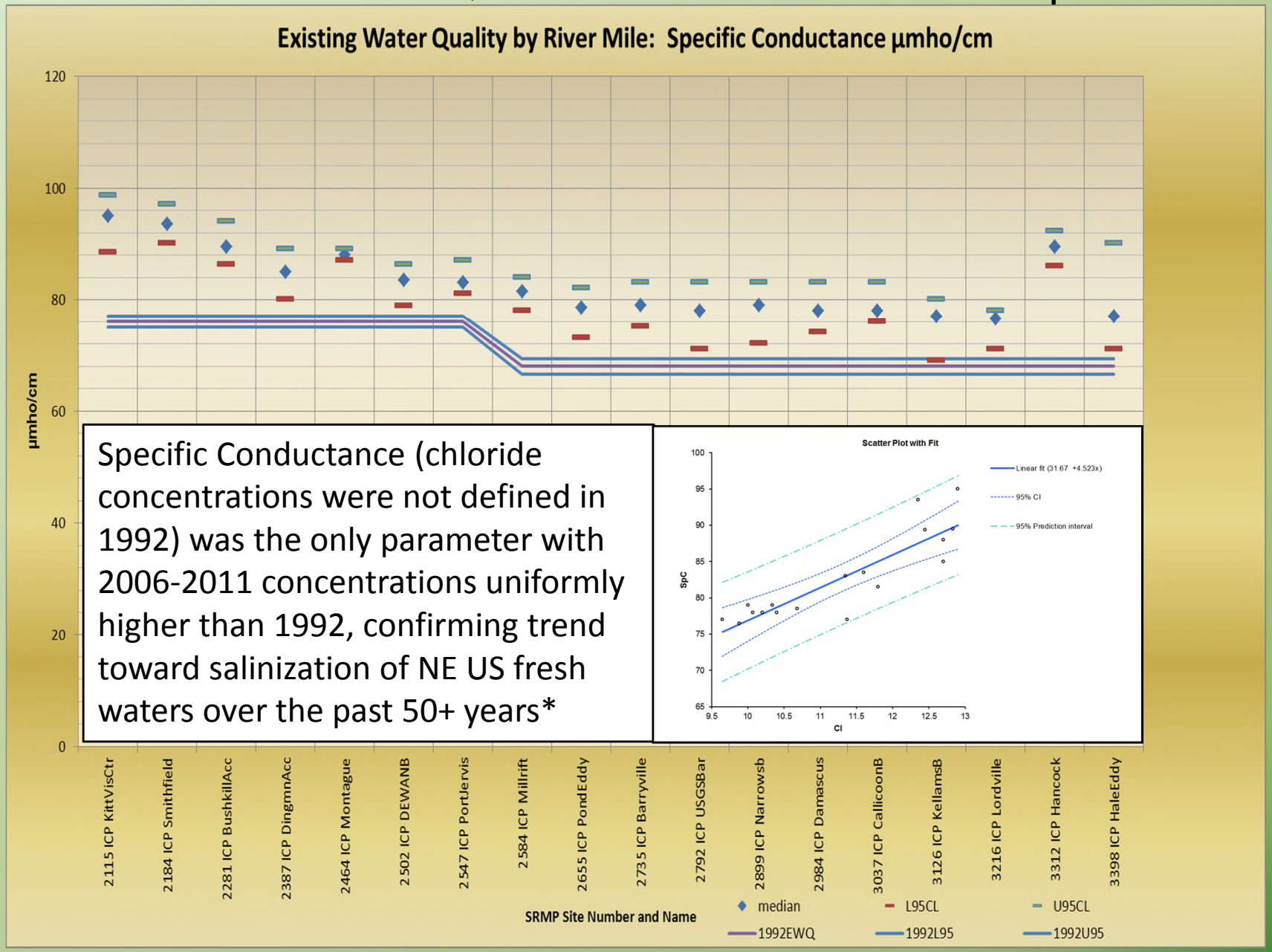
Many concentrations were much reduced since 1992, including most nutrients. Probable explanations: improved MDL's; abandoning use of replacement values for non-detects and forcing normality of distributions mathematically; but it is possible that water quality also simply improved. Policy implications of adoption of "new" targets have not yet been addressed.

UPDE and DEWA EWQ: Reach-Wide 1992 vs. Site Specific 2011



Some results matched up well between the two periods – TKN, DO, pH, fecal coliforms, temperature, alkalinity, hardness. In essence, these targets remain unchanged from 1992, though it is now easier to assess measurable change.

UPDE and DEWA EWQ: Reach-Wide 1992 vs. Site Specific 2011



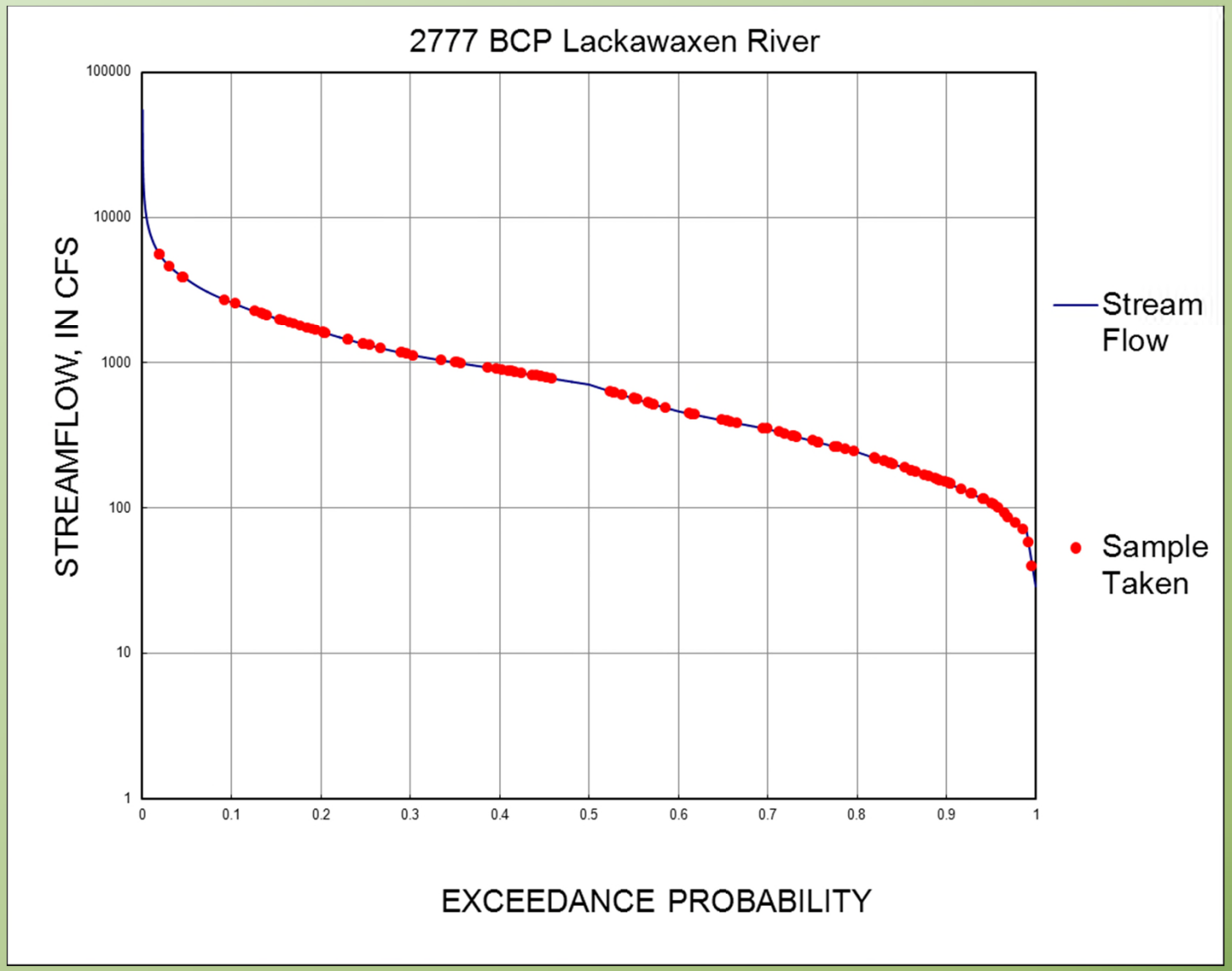
*Kaushal et. al. 2005. Increased salinization of fresh water in the northeastern United States. Proc. Nat. Acad. Sci. 102 (38): 13517-13520

DRBC Reports in Progress

- UPDE/DEWA EWQ report:
  - Site-Specific EWQ packets are available for all 71 sites.
  - 6 more sites under characterization by USGS and NPS in the Marcellus Shale region
  - Packets include EWQ tables, watershed maps and watershed characteristics (including flow duration curves, SPW-permitted dischargers and USGS Stream Stats summaries).
  - Packets are to be posted on DRBC website once the map atlas is complete; and linked to DRBC interactive watershed map.

- LDEL Measurable Change Assessment 1 report:
  - We are working on a decision tree of statistical methods that define what constitutes “measurable change to EWQ.” The report should be complete by December 2014.

Sample EWQ Packet



Flow duration curve with samples – verifies coverage of hydrologic regime for study period

Sample EWQ Packet

Site-Specific definition of Existing Water Quality shows:

Parameter

Number of data

Median concentration

Lower 95% confidence interval

Upper 95% confidence interval

Period of data record and data source(s)

Existing Water Quality: 2777 BCP Lackawaxen River, PA

Parameter	N	median	L95CL	U95CL	Period of Record (May-Sep data)
Alkalinity as CaCO3, Total mg/l	79	15.00	14.00	15.80	1999-2011 SRMP, PADEP
Aluminum, Dissolved, mg/l	15	0.002	0.001	0.005	2009-2010 SRMP archived samples
Ammonia-Nitrogen as N, Total mg/l	78	0.016	0.015	0.016	1999-2011 SRMP, PADEP
Barium, Dissolved mg/l	15	0.017	0.017	0.020	2009-2010 SRMP archived samples
Calcium, Dissolved mg/l	15	6.98	6.42	7.80	2009-2010 SRMP archived samples
Chloride, Total mg/l	68	10.90	10.20	11.60	2006-2011 SRMP, PADEP
Dissolved Oxygen (DO) mg/l	72	9.00	8.90	9.40	1999-2011 SRMP, PADEP
Dissolved Oxygen Saturation %	40	96	96	98	2007-2011 SRMP
Enterococcus #/100ml	45	14	9	21	2007-2011 SRMP
Escherichia coli #/100ml	45	9	5	16	2007-2011 SRMP
Fecal coliform #/100ml	73	18	11	30	1999-2011 SRMP, PADEP
Hardness as CaCO3, Total mg/l	79	23.0	22.2	24	1999-2011 SRMP, PADEP
Iron, Dissolved µg/l	15	3.7	3.2	10.6	2009-2010 SRMP archived samples
Magnesium, Dissolved mg/l	15	1.08	1.01	1.16	2009-2010 SRMP archived samples
Manganese, Dissolved µg/l	15	6.40	4.40	12.10	2009-2010 SRMP archived samples
Nitrate+Nitrite as N, Total mg/l	55	0.100	0.086	0.111	2007-2011 SRMP
Nitrogen as N, Total mg/l	65	0.366	0.341	0.393	2004-2011 SRMP, PADEP
Nitrogen, Kjeldahl as N, Total mg/l	55	0.257	0.248	0.290	2007-2011 SRMP
Organic Carbon, Total mg/l	14	3.75	3.10	4.40	1999-2004 PADEP
pH units	78	7.69	7.61	7.75	1999-2011 SRMP, PADEP
Phosphate as P, Total mg/l	98	0.013	0.011	0.015	2002-2011 SRMP, PADEP
Phosphorus as P, Total mg/l	94	0.020	0.019	0.023	1998-2011 SRMP, PADEP
Potassium, Dissolved mg/l	15	0.746	0.726	0.861	2009-2010 SRMP archived samples
Sodium, Dissolved mg/l	15	7.24	5.55	7.61	2009-2010 SRMP archived samples
Specific Conductance µmhos/cm	78	84.5	82.4	88.0	1998-2011 SRMP, PADEP
Strontium, Dissolved mg/l	15	0.026	0.024	0.028	2009-2010 SRMP archived samples
Sulfate, Total mg/l	37	6.32	6.11	6.58	2009-2010 SRMP archived samples
Temperature, Water, degrees C	78	18.8	17.8	19.7	1999-2011 SRMP, PADEP
Total Dissolved Solids (TDS) mg/l	92	51.5	50.0	52.8	1999-2011 SRMP, PADEP
Total Suspended Solids (TSS) mg/l	73	2.45	2.00	3.10	1999-2011 SRMP, PADEP
Turbidity NTU	54	2.78	1.91	7.25	2006-2011 SRMP

Two-tailed confidence limits were used for these EWQ targets. Calculated 12/18/2012 rll DRBC

Note: All data are May to September season. Additional data are available for the October to April "non-seasonal" period, but data are insufficient in number for establishment of site-specific existing water quality targets.

Sample EWQ Packet

Descriptive Statistical Plots of Each Parameter:

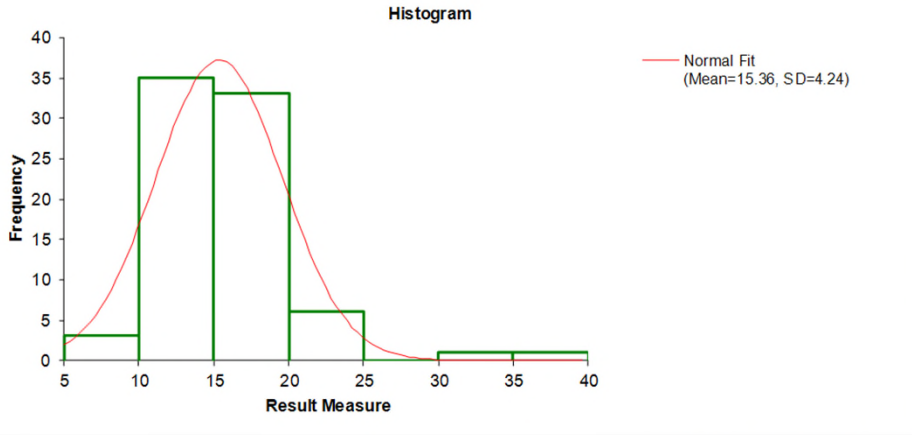
Frequency histogram

Box Plot (concentrations)

Parametric and Nonparametric descriptive statistics

Tests of Skewness, Kurtosis and Normality

Performed by	Alkalinity as CaCO3, Total mg/l Robert Limbeck	Date	18 December 2012



n	79		
Mean	15.36	Median	15.00
95% CI	14.41 to 16.30	95.8% CI	14.00 to 15.80
SE	0.477		
		Range	29.0
Variance	17.96	IQR	3.93
SD	4.24		
95% CI	3.66 to 5.02	Percentile	
		0th	7.00 (minimum)
CV	27.6%	5th	10.09
		25th	13.03 (1st quartile)
Skewness	1.96	50th	15.00 (median)
Kurtosis	7.58	75th	16.97 (3rd quartile)
		95th	21.85
Shapiro-Wilk W	0.86	100th	36.00 (maximum)
p	<0.0001		

Sample EWQ Packet

Comparisons of annual concentrations for each parameter:

Box Plot – black (median and percentiles)

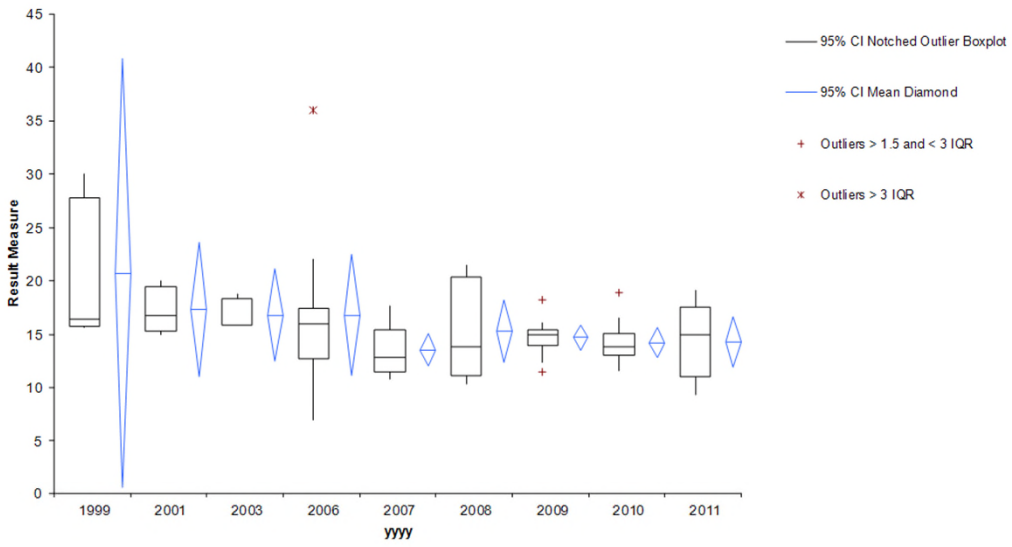
Diamond Plot – blue (means and confidence intervals)

Outliers - red

Data table of annual stats

Alkalinity as CaCO3, Total mg/l by YYYY

Performed by: Robert Limbeck Date: 18 December 2012



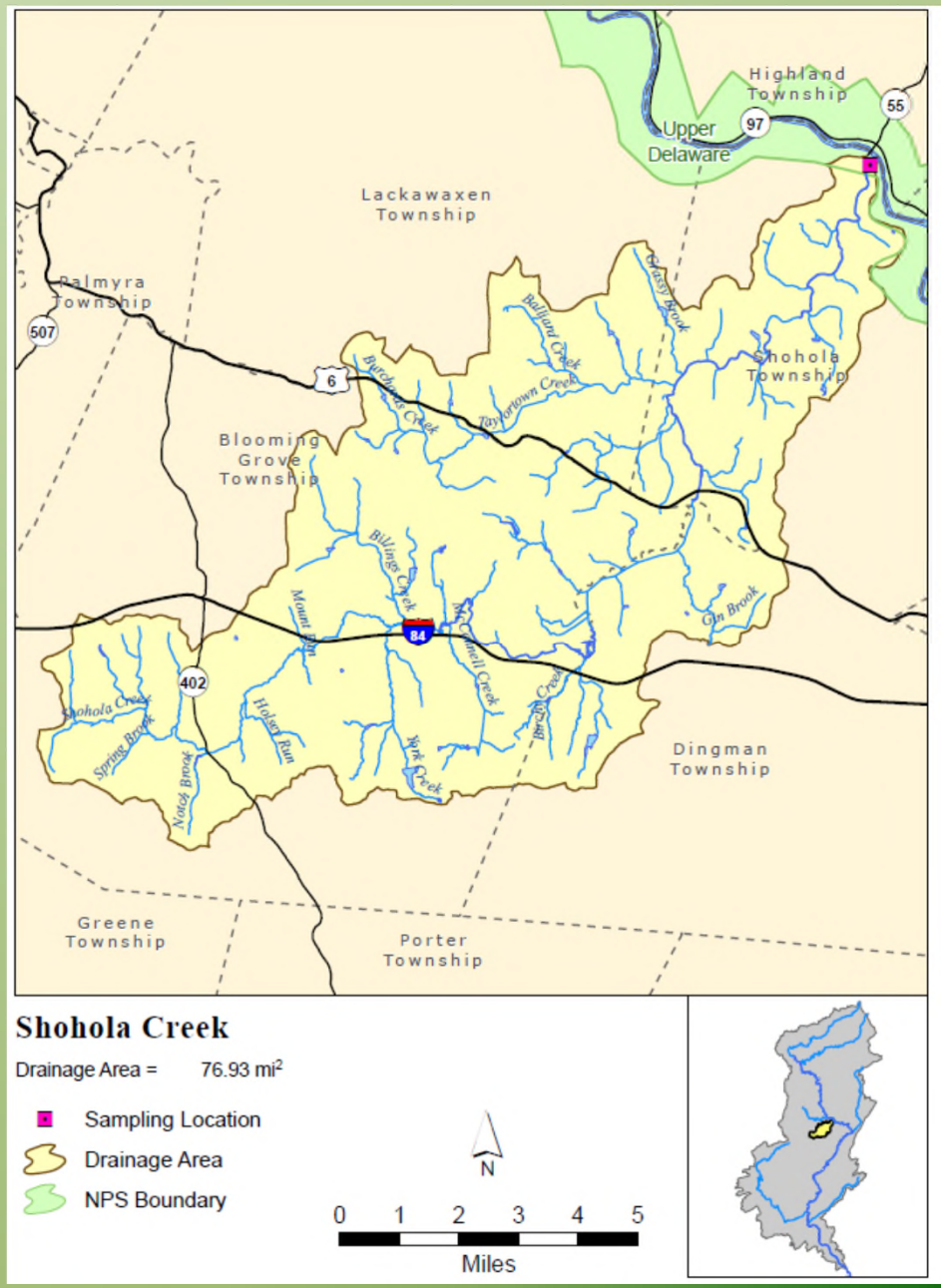
Result Measure by yyyy	n	Mean	95% CI	SE	SD
1999	3	20.67	0.56 to 40.77	4.672	8.093
2001	3	17.27	10.98 to 23.56	1.462	2.532
2003	3	16.80	12.50 to 21.10	1.000	1.732
2006	10	16.80	11.15 to 22.45	2.498	7.899
2007	11	13.51	12.00 to 15.02	0.679	2.251
2008	11	15.27	12.37 to 18.18	1.303	4.323
2009	11	14.69	13.49 to 15.89	0.538	1.786
2010	11	14.21	12.82 to 15.60	0.624	2.070
2011	11	14.29	11.94 to 16.64	1.056	3.502

Result Measure by yyyy	n	Min	1st Quartile	Median	95% CI	3rd Quartile	Max	IQR
1999	3	15.6	15.73	16.40	- to -	27.73	30.0	12.00
2001	3	15.0	15.30	16.80	- to -	19.47	20.0	4.17
2003	3	15.8	15.80	15.80	- to -	18.30	18.8	2.50
2006	10	7.0	12.75	16.00	10.00 to 22.00	17.42	36.0	4.67
2007	11	10.8	11.47	12.80	11.40 to 16.20	15.43	17.6	3.97
2008	11	10.3	11.17	13.80	10.60 to 21.20	20.38	21.5	9.22
2009	11	11.5	13.88	15.00	12.40 to 16.10	15.45	18.2	1.57
2010	11	11.6	13.03	13.80	12.10 to 16.50	15.10	18.9	2.07
2011	11	9.3	11.03	14.90	9.30 to 18.40	17.53	19.1	6.50

Sample EWQ Packet

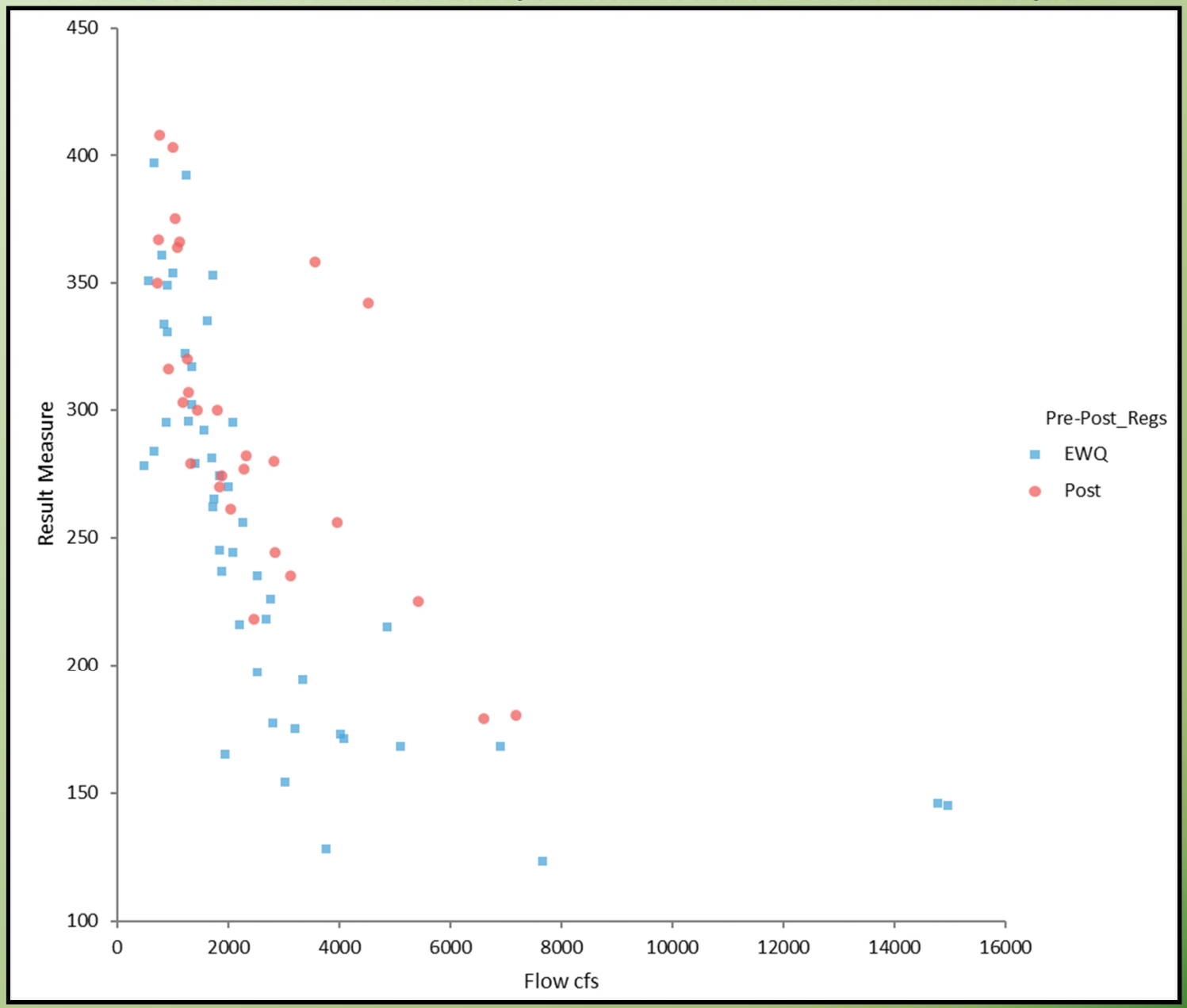
Watershed Atlas (entire watershed and HUC-12 sub-watersheds if applicable)

Control Point Location
Watershed Boundaries
Delaware Basin Watershed Location
Wild & Scenic River Boundaries
Stream Network
Transportation Routes
Political Divisions / Towns
Topography
Land Use / Land Cover
Tabular Summary from StreamStats
SPW Permits

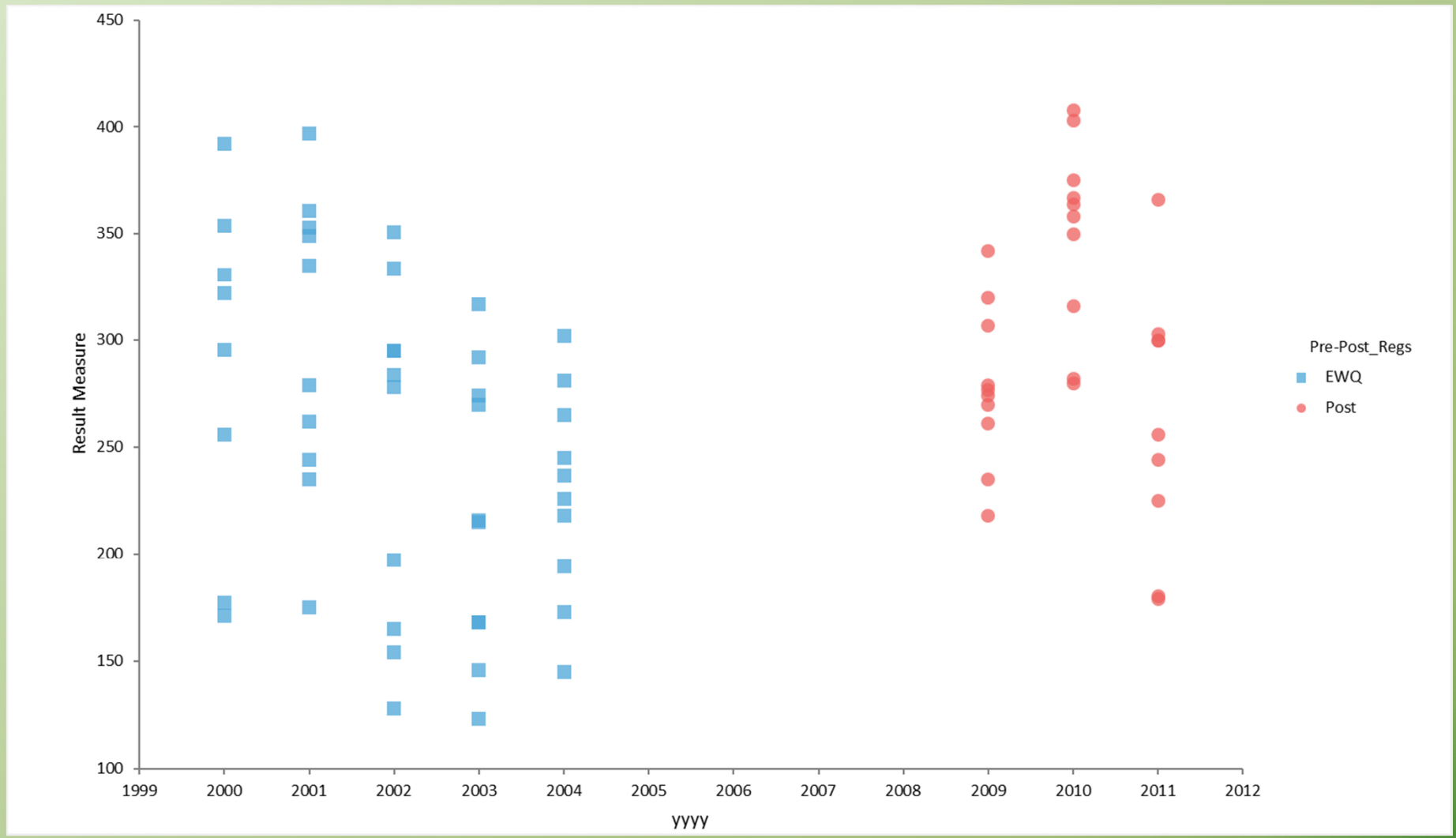


USING THE CONTROL POINT APPROACH TO MONITOR AND MANAGE TEMPORALLY, SPATIALLY, AND IN CONSIDERATION OF FLOW

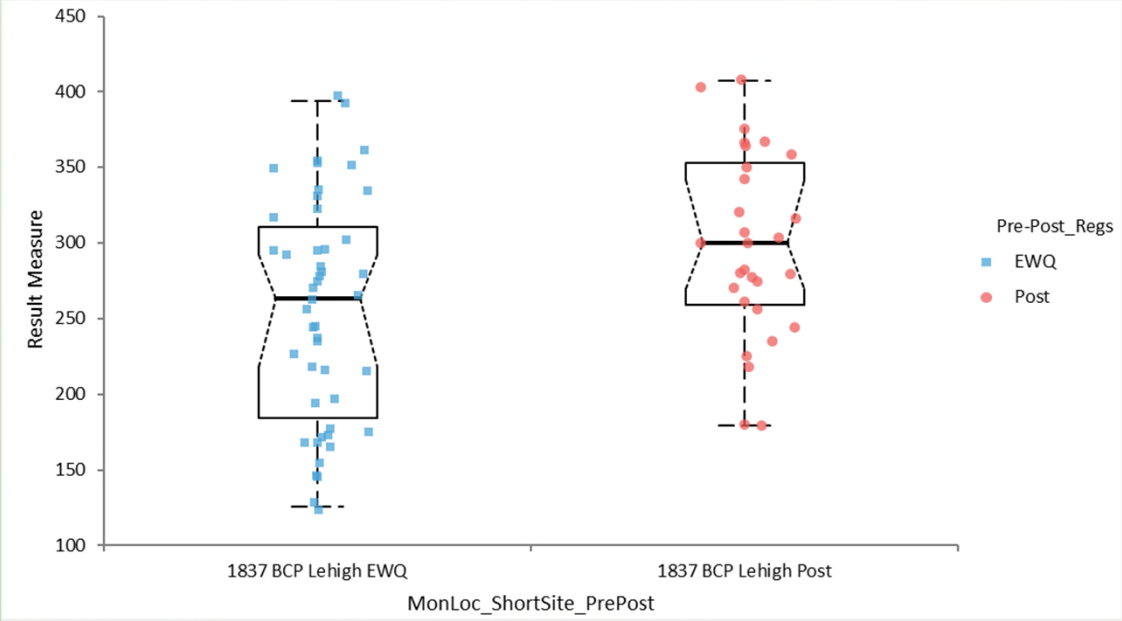
WITHIN SITE PRE/POST DATA PLOTTED WITH FLOW: SPECIFIC CONDUCTANCE, LEHIGH RIVER AT EASTON, PA



WITHIN SITE PRE/POST DATA PLOTTED ANNUALLY: SPECIFIC CONDUCTANCE, LEHIGH RIVER AT EASTON, PA



WITHIN SITE PRE/POST BOX PLOTS AND KRUSKAL-WALLIS COMPARISON: SPECIFIC CONDUCTANCE, LEHIGH RIVER AT EASTON, PA



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1837 BCP Lehigh EWQ	48	1155.4	24.07
1837 BCP Lehigh Post	29	1912.4	65.95

H statistic	6.13
X^2 approximation	6.13
DF	1
p-value	0.0133 [1]

H0: $\theta_1 = \theta_2 = \theta...$

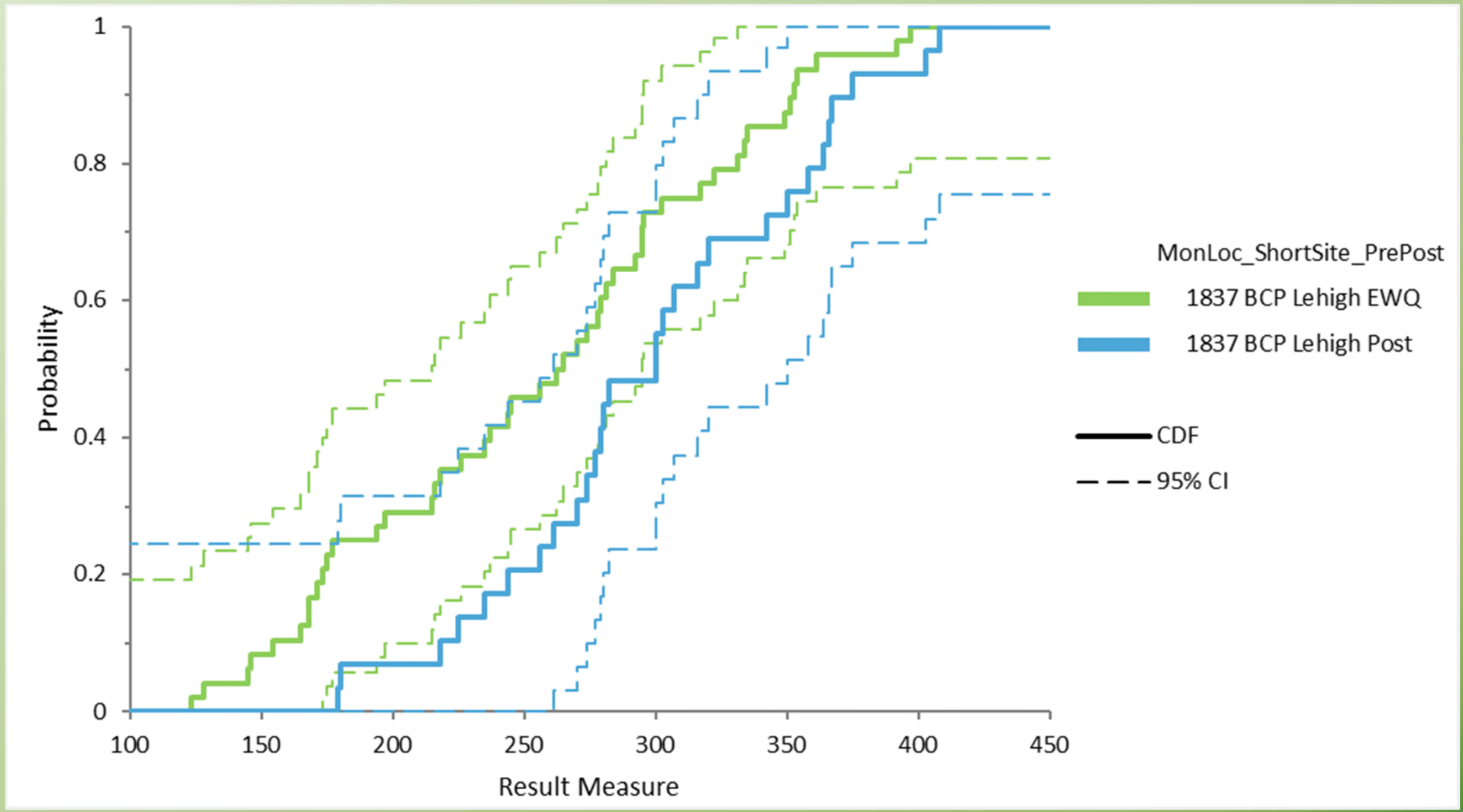
The median of the populations are all equal.

H1: $\theta_i \neq \theta_j$ for at least one i,j

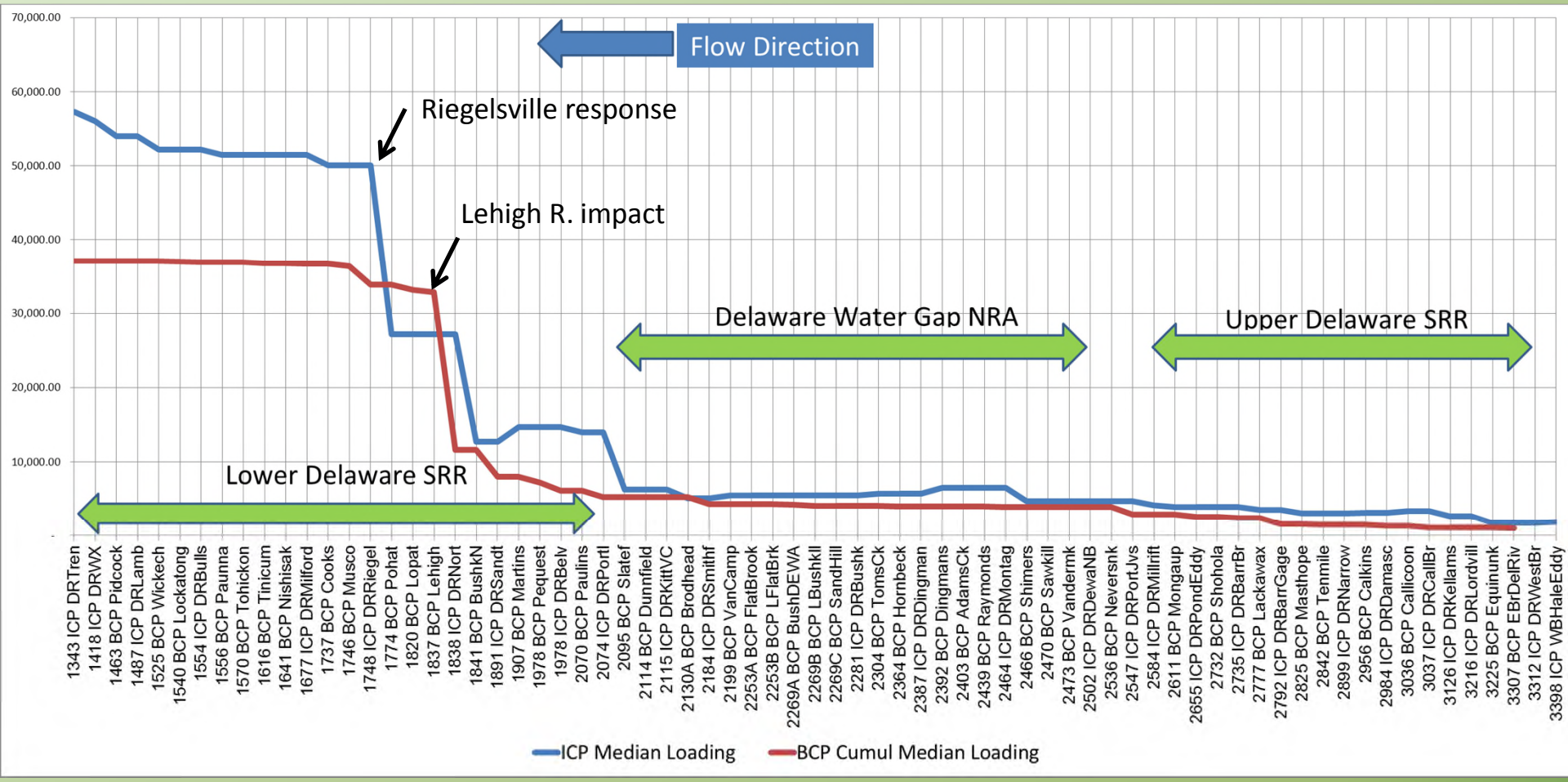
The median of the populations are not all equal.

[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

WITHIN SITE PRE/POST COMPARISON OF CUMULATIVE DISTRIBUTION FUNCTIONS: SPECIFIC CONDUCTANCE, LEHIGH RIVER AT EASTON, PA

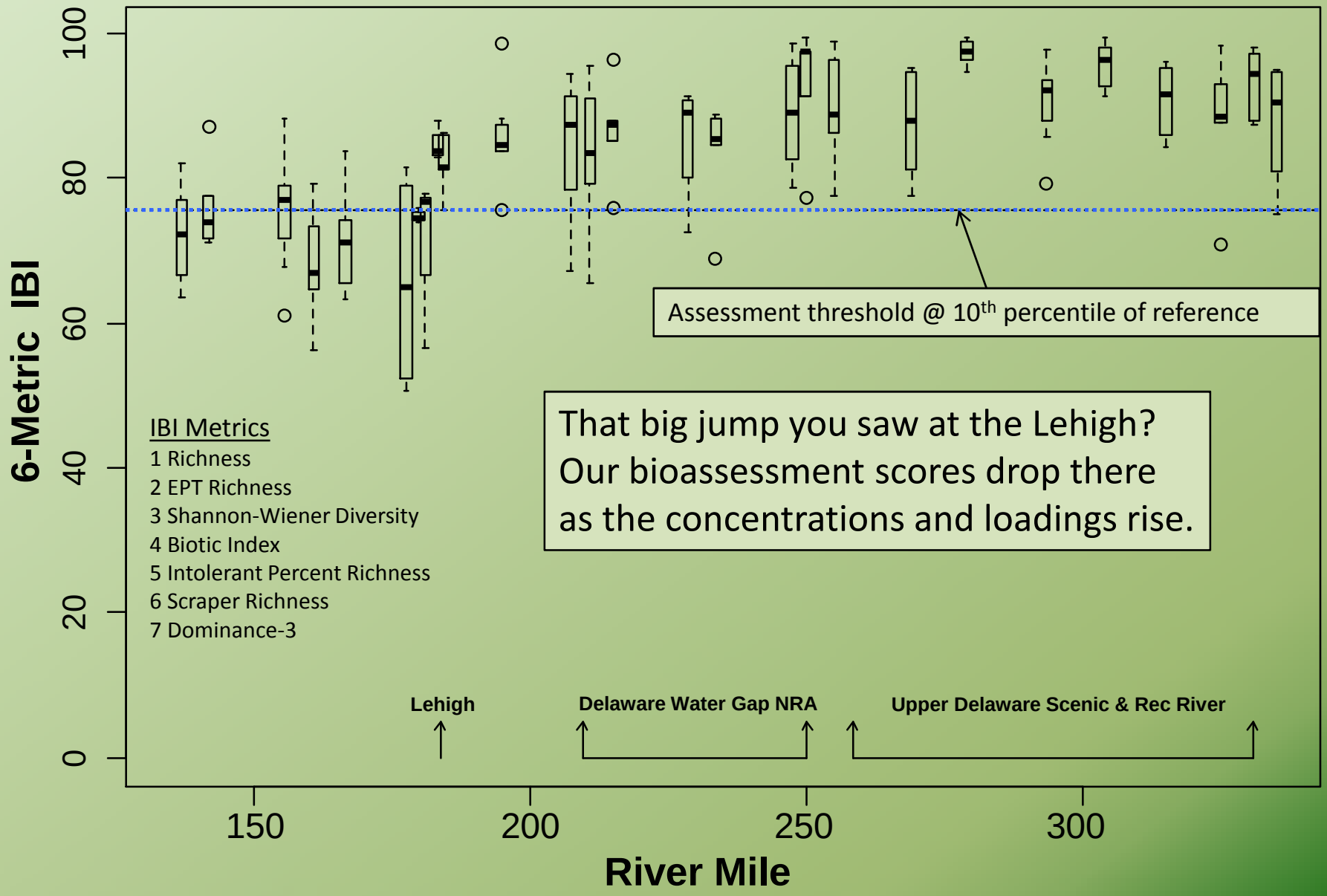


Other Data Views: Loadings Plots (no Pre/Post shown)



Total Nitrogen (lbs./day) May to September loadings past Delaware River ICPs vs. cumulative loadings supplied by tributaries. The modelers love these plots… For example, we can use mass balance equations to calculate where and how much to reduce Nitrogen loadings in order to improve downstream water quality. BMPs, trading, other less-regulatory tools become employed; and public participation is more focused.

Delaware R. Bioassessment: 6-metric IBI



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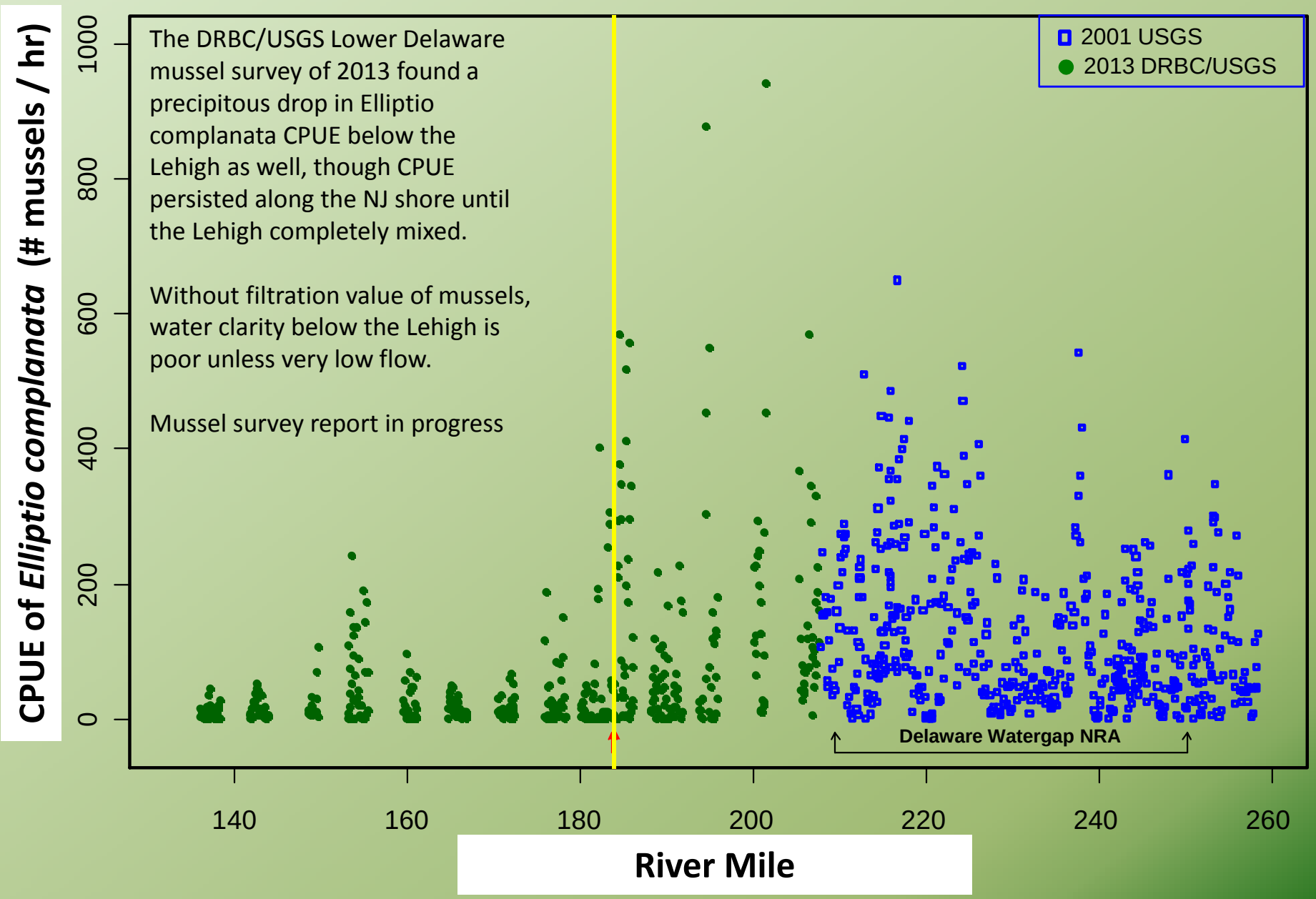
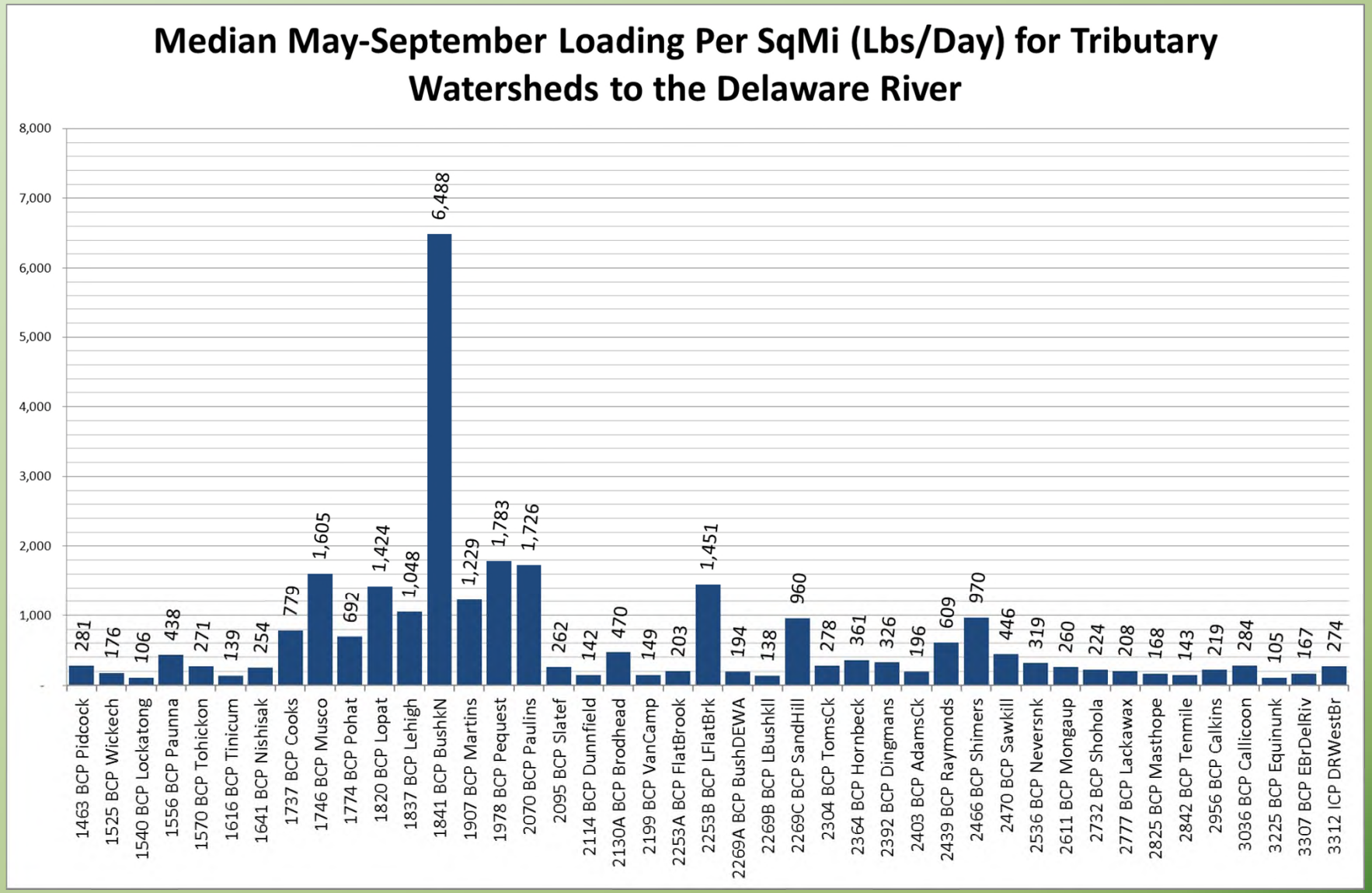


Other Data Views: Loadings Normalized by Watershed Area (TDS, lbs./day/square mile) – no Pre/Post shown



Good indicator relating to land use. I use this to rank watersheds for priority attention.

Data Availability

Contact Bob Limbeck (Robert.Limbeck@drbc.state.nj.us, 609-883-9522 x 230)

The reports aren't complete yet, but will be available on:

The new DRBC interactive map:

http://www.state.nj.us/drbc/basin/map/interactive-map.html

Special Protection Waters Data and Publications:

http://www.state.nj.us/drbc/programs/quality/spw.html

THANKS!

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